DEISS

Investigation of Inverse Time Limit Overload Relays

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INVESTIGATION OF INVERSE TIME LIMIT OVERLOAD RELAYS

BY

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William Charles Deiss

ENTITLED Investigation of Inverse Time Limit Overload Relays

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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INVESTIGATION OF INVERSE TIME LIMIT OVERLOAD RELAYS.

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I-INTRODUCTION.

Due to the rapid increase of large central stations and distribution systems, the matter of proper overload protection is growing more and more important. To secure this protection the inverse time limit overload relay is a necessary adjunct, and therefore the attention of the engineering profession is being given to this particular form of protective apparatus.

In this investigation particular stress is laid upon the selective operation of inverse time limit relays. This is quite in keeping with the present day demands, since the most important use of the relays is in the large distribution systems.

INVESTIGATION OF INVERSE TIME LIMIT OVERLOAD RELAYS.

II-FUNCTIONS AND USES OF INVERSE TIME LIMIT RELAYS.

The inverse time limit overload relay is ,as the name implies,an auxilliary apparatus which operates at overload to open an electrical circuit, the greater the overload, the less the time being taken to operate. Its purpose is to protect the system from severe overload or short circuit, at the same time insuring continuity of service and protection against loss of synchronous load as far as possible. Also by means of its selective timing action to disconnect only such portions of the circuits which are in trouble.

Primarily, the inverse time relay consists of an electrical device which is in conjunction with the main circuit, either in series or by means of a current transformer. It is so designed that when overload occurs in the circuit it begins to operate. By some means of retardation, either mechanical, electrical, or magnetic, it takes a certain time to operate an auxilliary circuit which opens the circuit breaker. This time action may be regulated in order that it will suit the particular type of service for which the relay is used.

All types of these relays are adjustable, both for current and time. The accuracy of this adjustment is one of the main features of a relay. The current adjustment is the setting of the relay to begin to operate at some value of current, usually slightly above the full load value.

For the setting of the time element, the characteristics of the generators and of the system must be known, as well as the characteristics of the automatic apparatus, circuit breakers,

regulators, and so forth. The following information is generally necessary:

(1) The "instantaneous" short-circuit value of the current through each conductor to which the relays may be applied.

(2) The "sustained" short-circuit value of the current through each conductor.

(3) The time in changing from (1) to (2).

(4) The time required for the various automatic circuit breakers to open the circuit after the application of current to their coils.

(5) The safe current-opening capacity of the various circuit breakers.

(6) The time characteristics of the various relays.

The value of the short-circuit current depends partially upon the characteristics of the generator used and partially upon the impedance of the circuit to the point where the relays are connected. The further the point of application is from the generator, and the more apparatus is included between, the less will be the difference between the instantaneous short-circuit value and the sustained short-circuit value of the current. Figure (1) shows the time elapsing between these two conditions for certain generators. Here it is seen that for these generators the current has increased to one-fifth of the initial value in less than a second. Other generators may show a greater divergence in this respect.

The current wave at short-circuit may be symmetrical or unsymetrical up to .15 or .25 second, depending upon the point of the voltage wave at which the short-circuit is closed, and the

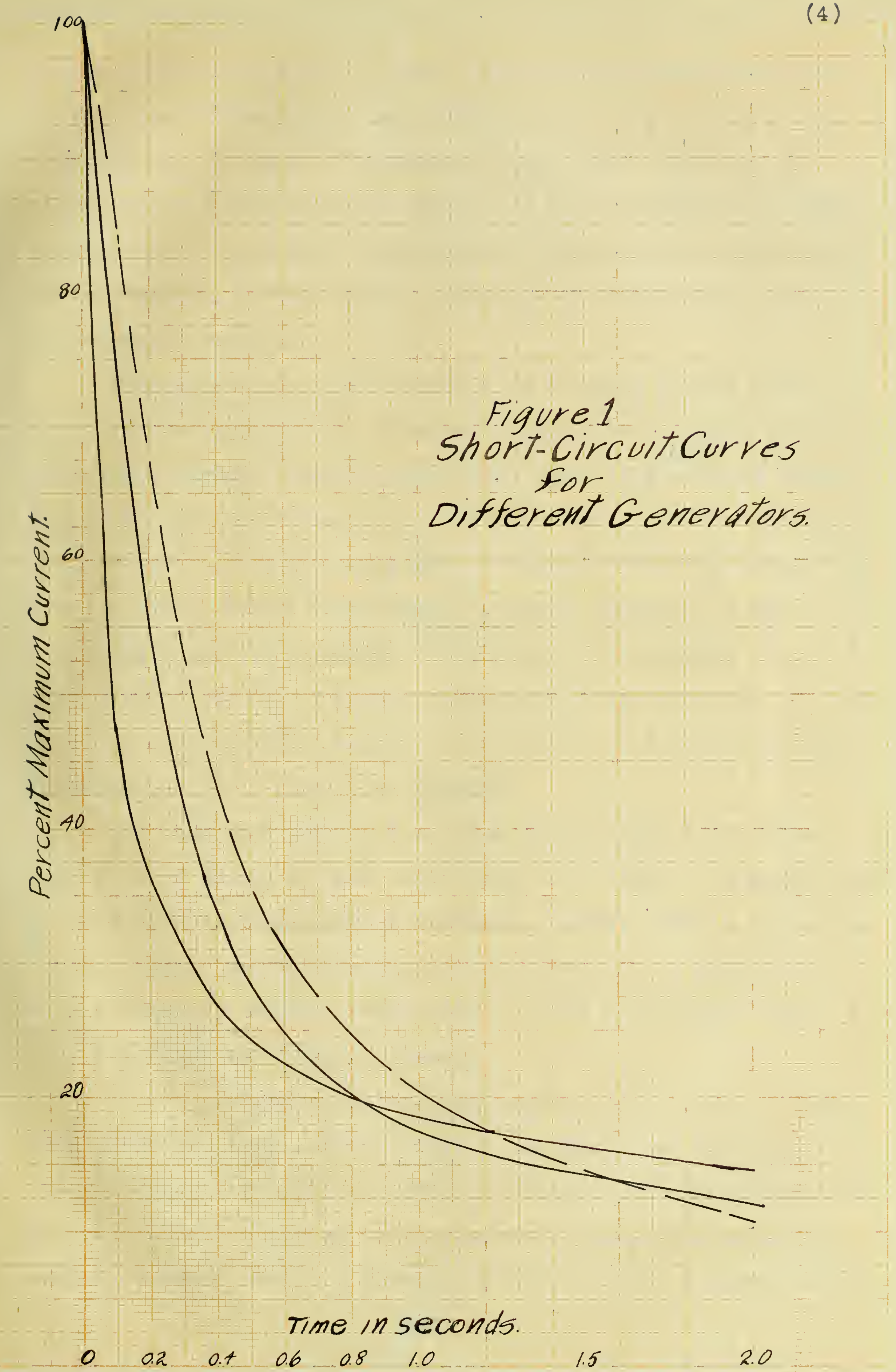
Figure 1
Short-Circuit Curves
for
Different Generators.
Percent Maximum Current.
100
80
60
40
20
Time in seconds.
0
0.2
0.4
0.6
0.8
1.0
1.5
2.0

greater the dissymmetry the more the initial current decrease is affected. After this time, however, the wave is fairly symmetrical and the rate of decrease is the same. The rate of decrease for a single-phase circuit is faster than for a three-phase circuit, although the sustained single-phase short-circuit current value is about 50 per cent greater than that of the three-phase circuit.

In general, the time elements of a relay should be as short as possible without causing the circuit breakers to open before the current has died down to a value that can be safely opened by the particular circuit breaker used, or without opening before it is really necessary. In most cases the system can stand a fairly heavy overload for several seconds. In case of a "swinging short" or similar disturbance, the overload goes off very quickly and it is rarely necessary to open the circuit. In this way continuity of service is insured. Also undue loss of synchronous load is provided against.

The characteristics of a relay can be judged from its time-current curves. These curves show the time to open the circuit for different amounts of overload current. They are plotted for different time settings and in this way it is possible to tell the proper setting needed for for the particular class of work for which the relay is used.

Figure (2) shows-time-current curves for a relay of the purely inverse time element. Here it is seen that the time of trip becomes very small for about 20 times full load current and that the time for the various settings becomes practically the same. This would not give adequate protection for a severe short-

circuit, in which case the current may reach the value of 40 or 50 times full load current. This is because the circuit breakers could not safely open the circuit at once, owing to the instantaneous value of the short-circuit current. However, conditions of this sort are not common in the average system. With well-designed circuit breakers, a relay having these characteristics would afford protection for simple overloads.

Figure (3) shows time-current curves for a relay which inverse time characteristics up to about 4 times full load current. From this point on the time of trip is constant for all values of current. The advantages of these characteristics are quite obvious. Regardless of the severity of the short-circuit, the time required to trip the circuit-breaker is of a definite value. This affords protection of the circuit-breaker and the other apparatus and it also insures continuity of service.

The greatest value, however, of a relay with these characteristics, is its selective operation. In most large distribution systems, substations are in series as shown in figure (5). Here the symbol X represents the inverse time relays.

Figure 5.

Now in order to preserve continuity of service, the relays at D are set for the least time, and those at the plant A for the greatest time. If the ground or short-circuit occurs beyond D, the relays at D before the others have time to operate. If trouble occurs between C and D, the relays at C will cut off the

trouble section, and so on.

Suppose that the time elements of the different relays in this case are set so that they will give curves similar to A, B, C, and D of figure (2). Assuming a moderate overload of about 4 times full load current, and assume that the trouble is between the plant A and sub-station B. From the curves we see that about 6 seconds would elapse before the trouble would be cleared. Again assume a short-circuit beyond D. Here we see that the breakers at D, C, B, and A would all be tripped, since the time value for each relay at this heavy current would be about the same. Now in the first case, the time taken to clear is too long, as it means that all synchronous load is lost. In the second case, all of the sections of the circuit have been opened when it is only necessary to open beyond.

Now, suppose that the time elements of the relays are as shown in the curves A, B, C, and D of figure (3). Here we see that the time between the minimum of each relay is always the same for overloads of greater than 4 times full load. It may also be seen that this time between is over half of a second in each case. This means that no matter how great the overload, the relays will act in their proper order and give good selective action. Also, the loss of synchronous load is greatly diminished.

A relay giving the latter form of curves is by far the best for use in selective operation and should also be recommended for the protection of single feeder circuits. However, the relay giving the first form of curves will probably give ample protection for the latter kind of circuit, especially if the interuption of service is not of great importance.

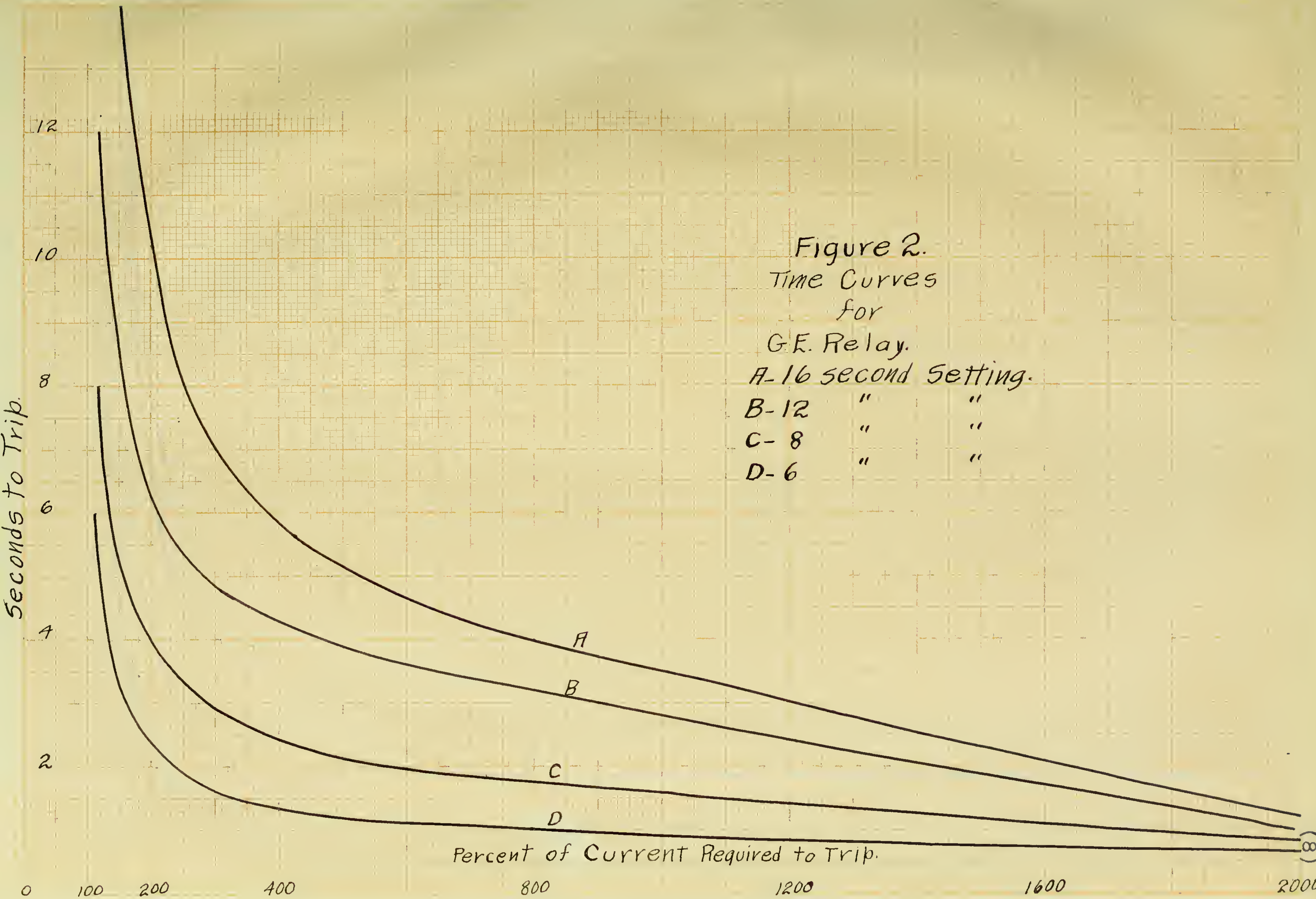

Figure 2.
Time Curves
for
G.E. Relay.

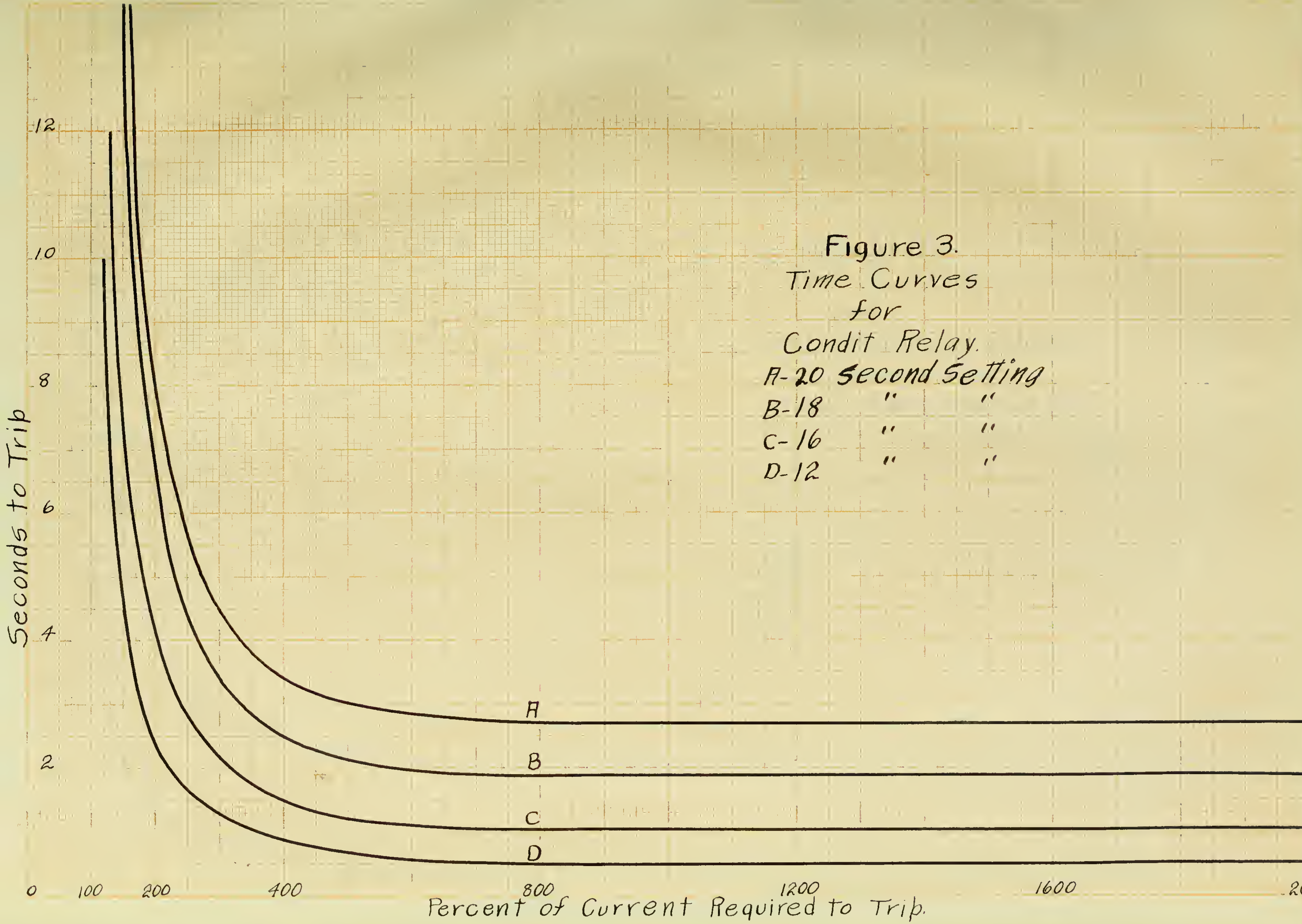
Figure 3.
Time Curves
for
Condit Relay.
A-20 Second Setting
B-18 " "
C-16 " "
D-12 " "
A
B
C
D
Seconds to Trip
12
10
8
6
4
2
0
100
200
400
800
1200
1600
2000
Percent of Current Required to Trip.

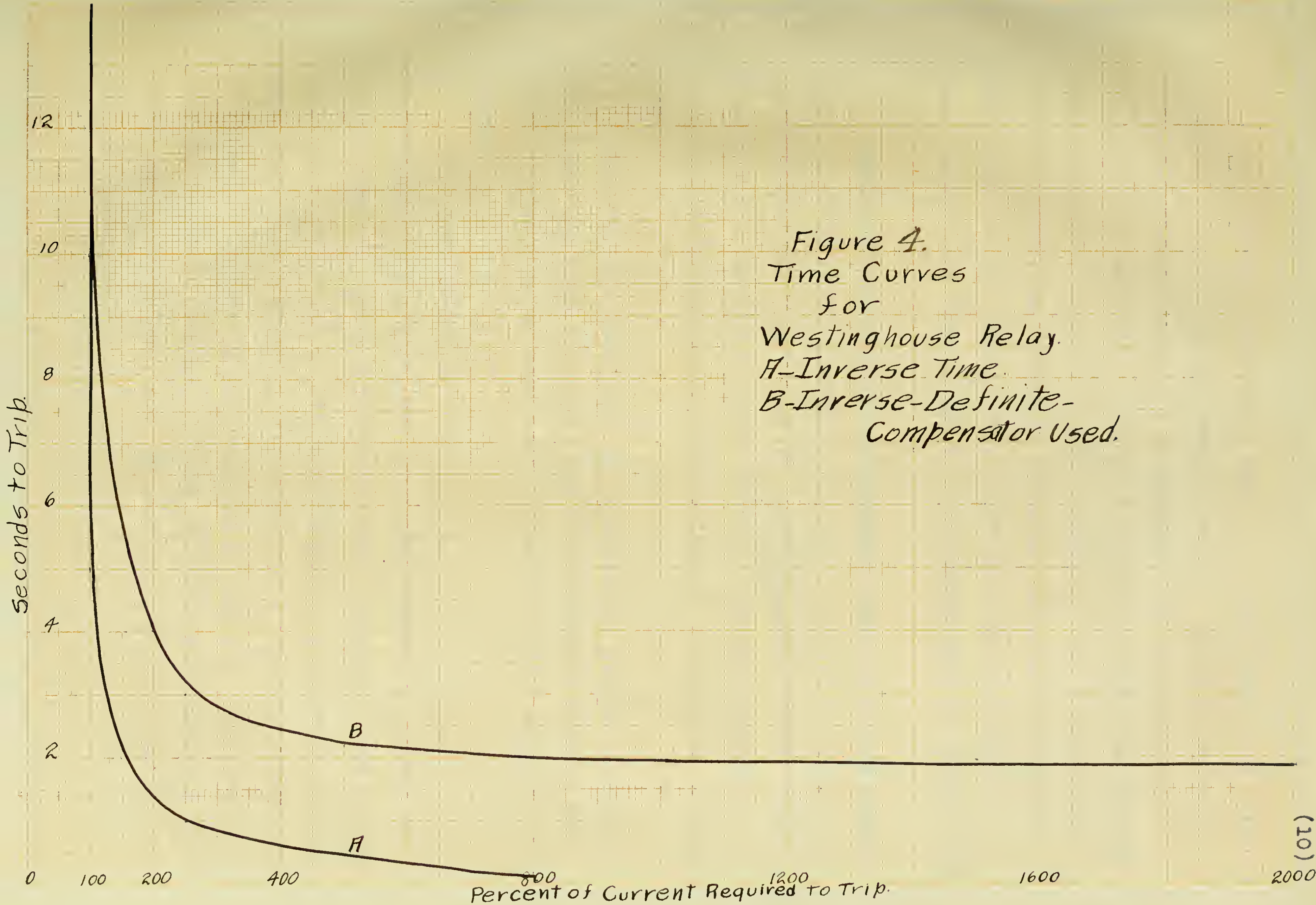

Figure 4.
Time Curves
for
Westinghouse Relay.
A-Inverse Time
B-Inverse-Definite-
Compensator Used.
Seconds to Trip.
12
10
8
6
4
2
0
100
200
400
800
1200
1600
2000
Percent of Current Required to Trip.
A
B

Again, a relay must have good re-setting qualities. That is, it should cease to operate when the current drops to about 80% of the value which caused it to operate, and at this point it should re-set instantly. In case of a swinging short or similar disturbance, the relay will start to operate due to the large current flowing, but it should re-set as soon as the trouble passes off and the current goes below the setting value. If it fails to do this, the circuit will be opened when it is not called for.

Another feature of a well-designed relay is a high power factor and low energy consumption. This is needed on account of the fact that the relay is often operated on instrument transformers and a low power factor and large energy consumption would cause inaccuracies in the readings of the various instruments.

Besides, the relay must be mechanically strong in order to with-stand the magnetic shocks and the mechanical impacts that it is subjected to at overloads of from 20 to 40 times full load current.

Many different types of relays have been designed to give the characteristics mentioned. The time element is secured in various manners, among which are bellows, dashpots, fans moving in liquids, expansion of metals and mercury, clock-work escapements, magnetic damping and the action of a repulsion motor. All of these are unreliable for general use with the exception of the bellows, magnetic damping, and the action of the repulsion motor. Relays employing these latter devices are now on the market and are used extensively.

III-CONNECTIONS OF RELAYS.

The inverse time relay may be used to protect single-phase, quarter-phase, or three-phase circuits. For a single-phase circuit one relay is needed, connected as shown in figure (6). This connection diagram and the ones following represent the solenoid type of relay, but the circuits are identical with all other types.

In a quarter-phase system, two relays are necessary, connected as shown in figure (7).

For a balanced three-phase system, one relay can be used with perfect safety. A three-phase motor load is an example of a circuit of this type. Figure (8) shows the connections.

In a three-phase system without neutral two relays, connected as shown in figure (9), afford the proper protection.

For a three-phase system with grounded neutral it is necessary to have three relays, connected as in figure (10).

In all of these connections, we see that a direct current tripping circuit is required to energize the tripping coil of the circuit breaker. This direct current is usually taken from the exciter bus of the station.

CONNECTION DIAGRAMS OF RELAYS.

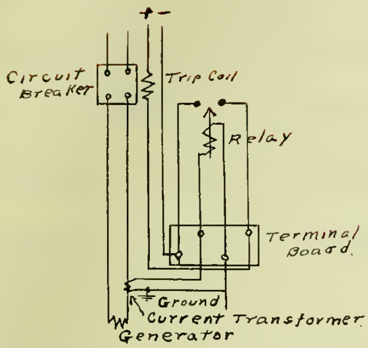

Fig. 6.

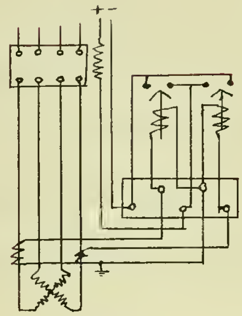

Fig. 7.

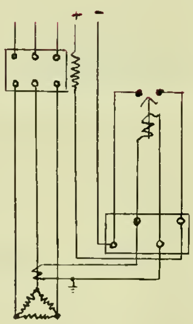

Fig. 8.

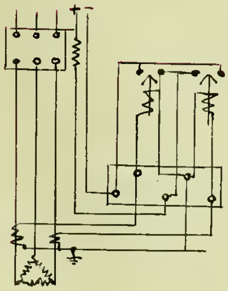

Fig. 9.

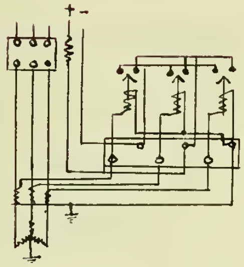

Fig. 10.

IV-DESCRIPTION AND CHARACTERISTICS OF DIFFERENT RELAYS.

The three types of relays named in Chapter II, namely, the bellows type, the magnetic damping or induction type, and the repulsion motor type are manafactured and marketed by the General Electric Co., the Westinghouse Electical and Manafacturing Co., and the Condit Electrical Manafacturing Co.,respectively. There are other companies which manafacture similar types, but their designs are not so good and they may be neglected in this consideration.

<u>THE G. E. BELLOWS TYPE RELAY</u>.- This type of relay consists essentially of a solenoid with an iron frame forming the support for the relay; a central plunger or armature of special design which is picked up or released by the magnetic action of the solenoid; a plunger rod which actuates the relay contacts, which are mounted above the solenoid on an insulated base; a diaphragm above the plunger to retard its movement; an adjustable valve which regulates the escape of air from the diaphragm; and a tube for the current calibration.

A cross-section of the relay is shown in figure (11). A solenoid, I, is enclosed in an iron frame, M. Through the core extends a plunger, J, to which is connected the rod, N, carrying the brass contact member, G. The plunger rod, N, is connected to the metal hood, E, to which is secured the lower part of the leather diaphragm, D. The diaphragm is attached to the top of the case by means of two rings made of helical springs, C. A thimble valve , A, is above the diaphragm and allows the escape of air through the opening, B. The valve is adjustable as shown by means of the screw. Above the solenoid, mounted on an insul-

ated block, H, are the two spring brass contacts, F. Below the solenoid is the calibration screw, O. Here the position of the plunger in the solenoid is regulated by the thumb-screw, K.

Figure (12) is a photo-graph of the relay complete and with cover on, showing single-pole, double-pole, and three-pole relays. The connection blocks are also shown. Here we see the markings on the calibration tube. By this means it is possible to regulate the position of the plunger and thus procure the proper current setting. The time setting is accomplished by means of regulation of the thimble valve. Raising the adjustment screw decreases the time element and lowering it increases the time element.

The action is as follows: When the current in the solenoid goes above the set value the plunger is picked up. The air pressure in the diaphragm retards its motion at a rate depending upon the amount of the overload. When the contact member strikes the spring brass contact fingers the tripping circuit is closed and the main circuit opened. The solenoid is at once de-magnetized and the plunger falls. At the instant the plunger starts to fall the thimble valve releases and allows it to fall quickly.

Time-current curves for this relay are shown in figure (2), and the characteristics are described fully in chapter II. These curves can be modified by means of a different design of bellows and solenoid, depending upon the class of work for which the relay is used.

<u>THE WESTINGHOUSE INDUCTION TYPE RELAY</u>.- In principle this type of relay is similar to the induction integrating watt-meter. It involves a rotating aluminum disc suitably mounted and actuated by a shifting electro-magnetic system. Instead of driving a

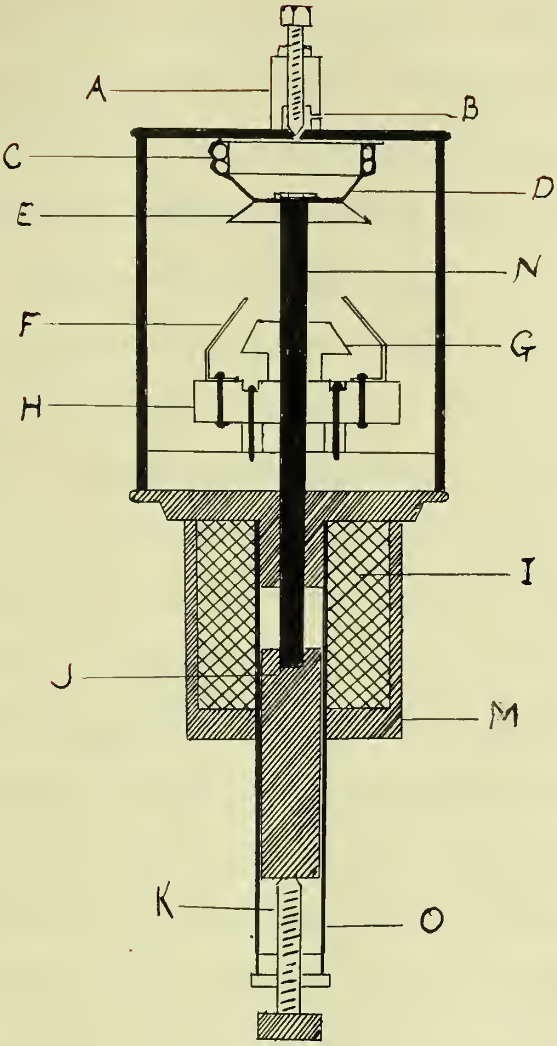

Fig. 11. Cross-section of G. E. Relay.

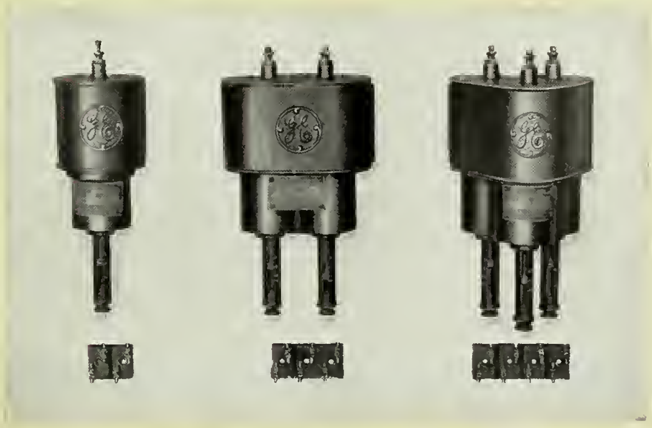

Fig. 12. G. E. Relays with cover.

registering dial, however, the shaft is controlled by a spring and a moving arm is arranged to close a contact connected to the tripping circuit of the circuit breaker. The disc travels through the air gaps of a pair of permanent magnets on one side and through the air gaps of a pair of electro-magnets on the other. This electro-magnet is wound only with the current coil, however, and the voltage connections are omitted.

Figure (13) shows an outline sketch of the mechanism. A is the aluminum disc attached to shaft B. This shaft is mounted with ball-bearing below and pin-bearing above. C is a spiral control spring attached at its inner end to the shaft B and at its outer end to an adjustable arm D terminating in an adjustable index arm E, which moves over the graduated scale F. G is a contact arm attached to the shaft B. The arm G terminates in a contact which in its travel engages a stationary insulated contact I, thereby completing the trip circuit. Below the index arm E is another index arm J, movable over the same scale. This arm is so arranged as to control and limit the motion of the contact arm G, but is itself limited by the position of the arm D attached to the index arm E. Index arm E, moved to the right, serves to increase the load setting of the relay by affecting the spiral springs so that a greater torque is required to make contact and vice versa. Index arm J, moved to the right, serves to increase the time element by allowing the contact arm to recede from the stationary contact, under the action of the control spring and limited by the stop arm K, thus increasing the distance and therefore the time to make contact and vice versa. L-L are permanent magnets, through the air gaps H-H of which the disc travels and on which they

exert a damping influence inversely to the speed of the disc, thereby giving the inverse time action to the relay. Diammetrically opposite to the permanent magnets is located the electromagnetic system separated from the permanent magnets by means of the magnetic shield M. For convenience these are shown in figure (14), where A and B are the laminated iron cores of the electro-magnets. Wound on A is a shunt winding C and a series winding D. On B is wound a shunt winding in series with C. The current coil D is arranged in three sections with taps brought out to the terminal block F on the relay base. This block comprises four terminal posts, three of which are arranged around the fourth and provided with a link that can be used to connect the central terminal with any of the three outside terminals, numbered respectively 1, 2, and 3. With the link connected to 1, (as shown) all of the turns of D are in circuit and the relay is in condition of maximum sensibility, i.e., it may be set for its minimum tripping values. Connected to 3 only about half of the turns are in circuit and the relay is in condition of minimum sensibility, i,e., it may be set for its maximum tripping values. The connection to 2 gives tripping values intermediate between 1 and 3.

The action of the relay is similar to that of the induction ammeter. With overload current flowing in coil D, the coil C acts as a secondary to D and energizes E, thus creating enough torque to rotate the disc. This movement is retarded by the action of the permanent magnets. The disc rotates until the contact is made and the circuit breaker opened. As soon as this occurs current ceases to flow in D and the spring causes the

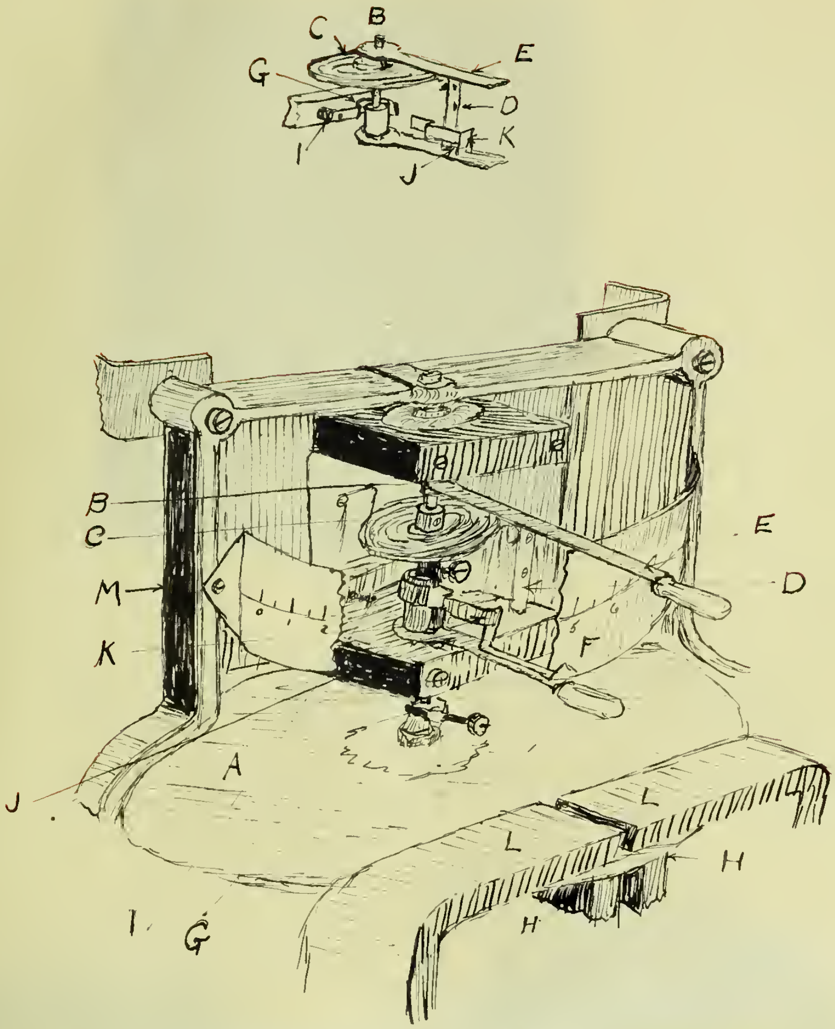

Fig. 13. Mechanism of Westinghouse Relay.

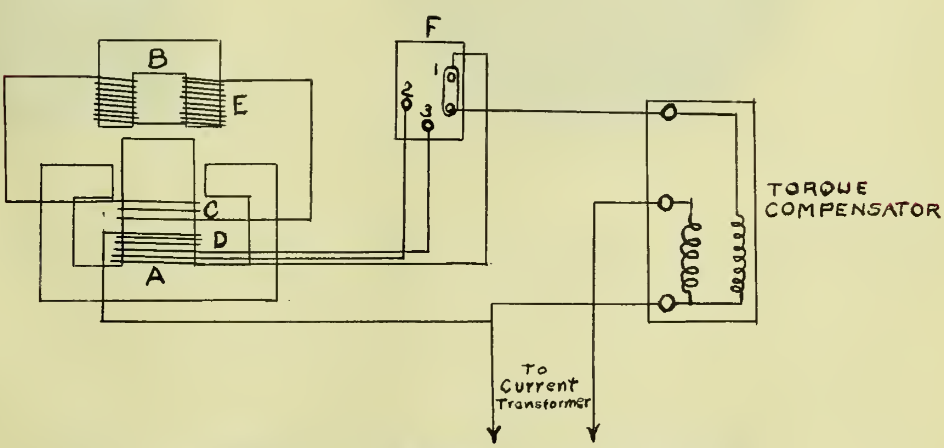

Fig. 14. Wiring of Westinghouse Relay.

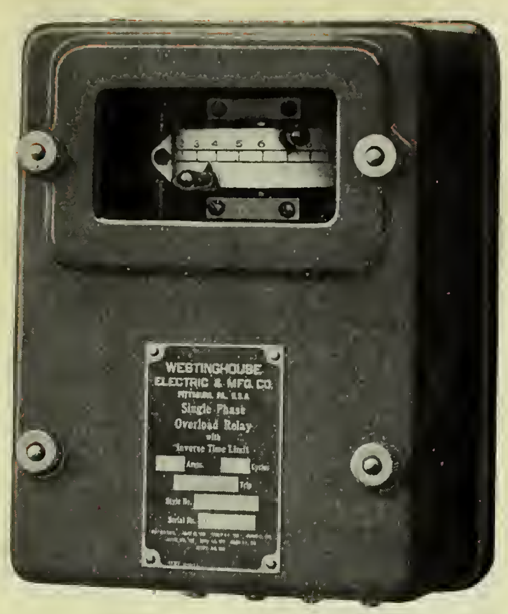

Fig. 15. Westinghouse Relay with Cover.

Fig. 16. Torque Compensator. Fig. 17. Relay with Compensator.

re-set at once.

The curve given given by this relay is shown in curve A, figure (4). This is the pure inverse time curve and is not very well adapted for selective work. To remedy this and give a curve having definite time element after 4 or 5 times full load current use is made of a device known as a"torque compensator". This consista of a miniature transformer connected between the series coil of the relay and the series transformer on the line. This small transformer has a laminated core of such cross-section that it begins to saturate as soon as the current increases beyond full load value. This prevents the current which passes through the relay from increasing at the same rate as it does in the main circuit. As soon as the core of the compensator becomes saturated, the current in the relay is practically constant. Hence we get a curve similar to curve B of figure (4). The characteristics of this curve are very similar to those shown in figure (3) and will do very well for selective action.

Figure (15) shows a photo-graph of the relay with cover. In figure (16) is shown a compensator for mounting on the rear of the switchboard.

Within the last year the relay has been manafactured with the torque compensator in the same case. Figure (17) shows this type, in which the whole is mounted in a glass watt-hour meter case.

THE CONDIT REPULSION MOTOR TYPE RELAY.- This type operates upon the principle of a repulsion motor which starts to rotate when overload comes on. It is very elaborate in structure and is a distinct departure from the prevailing types.

Figure (18) shows the general construction. An armature,1, is mounted in ball-bearings, 2, and arranged to rotate in a bipolar field. The field frame or magnetic circuit is split at 3, the upper field pole being permanently fastened to the main casting, 4, and the lower pole is fastened to a movable arm, 5, pivoted at 6, having a depending arm, 7, in contact with a compression spring, 8, used for the current calibration. A checknut, 9, moving over the threaded portion of the stud, 10, serves to vary the current calibration. The field coils, 11 and 12, are connected in multiple, the ends of which connect to the terminals, 13, mounted on the insulated block, 14. Current passes through these coils from a current transformer and when of suficient value to overcome the tension of the spring, 8, the lower or movable half of the motor field is attracted to the top. The weight of the lower half of the field is counter-balanced by a compression spring in the tube, 15. A worm wheel, 16, is mounted between two forked arms, 17, an extension of 5, and when moved in its upward position, meshes with the threaded portion of the shaft, 18.
A metallic pin, 19, is mounted in the movable arm, 20, but insulated therefrom by fibre tubing, 21. The arm, 20, is capable of being rotated on the shaft, 22, into any position, and held to the worm wheel by inserting the screw, 23, into the various holes, 24. The bearings for the shaft, 22, are mounted in adjustable eccentric bushings, 32, in to provide proper adjustment for the worm wheel. A pin, 33, serves as a stop for the worm wheel when it is released from the shaft, 18, so that the contact, 19, always starts at the same point for a given setting. The screw, 34, is used to get closer time adjustment than can be obtained

by the various holes, 24. Carried also by the arm, 5, is the contact post, 25, which engages the stationary contact, 26. These contacts are electrically connected with the brushes, 27, said brushes being adjustable by means of the ring, 28. Mounted on the insulated block, 29, are contacts, 30, which when bridged by the pin, 19, close the tripping circuit of the circuit breaker. Stop 31 is used to adjust the air gap at 3.

In action, current is supplied by the main circuit through current transformers to the field coils, 11 and 12. The armature is normally stationary with the brush circuit open. The lower half of the field now becomes the movable armature of which the coil, 11, is the magnetizing coil. When the magnetic pull is sufficient to raise the lower half of the magnetic circuit the metallic pin, 25, engages the stationary contacts, thus closing the armature circuit. The electro-magnet now becomes a repulsion motor. The flux set up in the field coils will induce current in the armature winding, thus causing rotation. It is to be noted that no current from the main circuit flows in the armature circuit, but an induced current. The load on the motor is practically constant and with a different value of current in the field, up to a certain point, between three and four times full load current, the induced current in the armature will increase in proportion to the current in the field coils. The torque and speed are increased accordingly. After this latter point, the magnetic circuit becomes saturated, due to the design of the coils. From here on the induced current will be practically constant, and hence the speed will also be constant. As the distance through which the contact, 19, travels is fixed, the

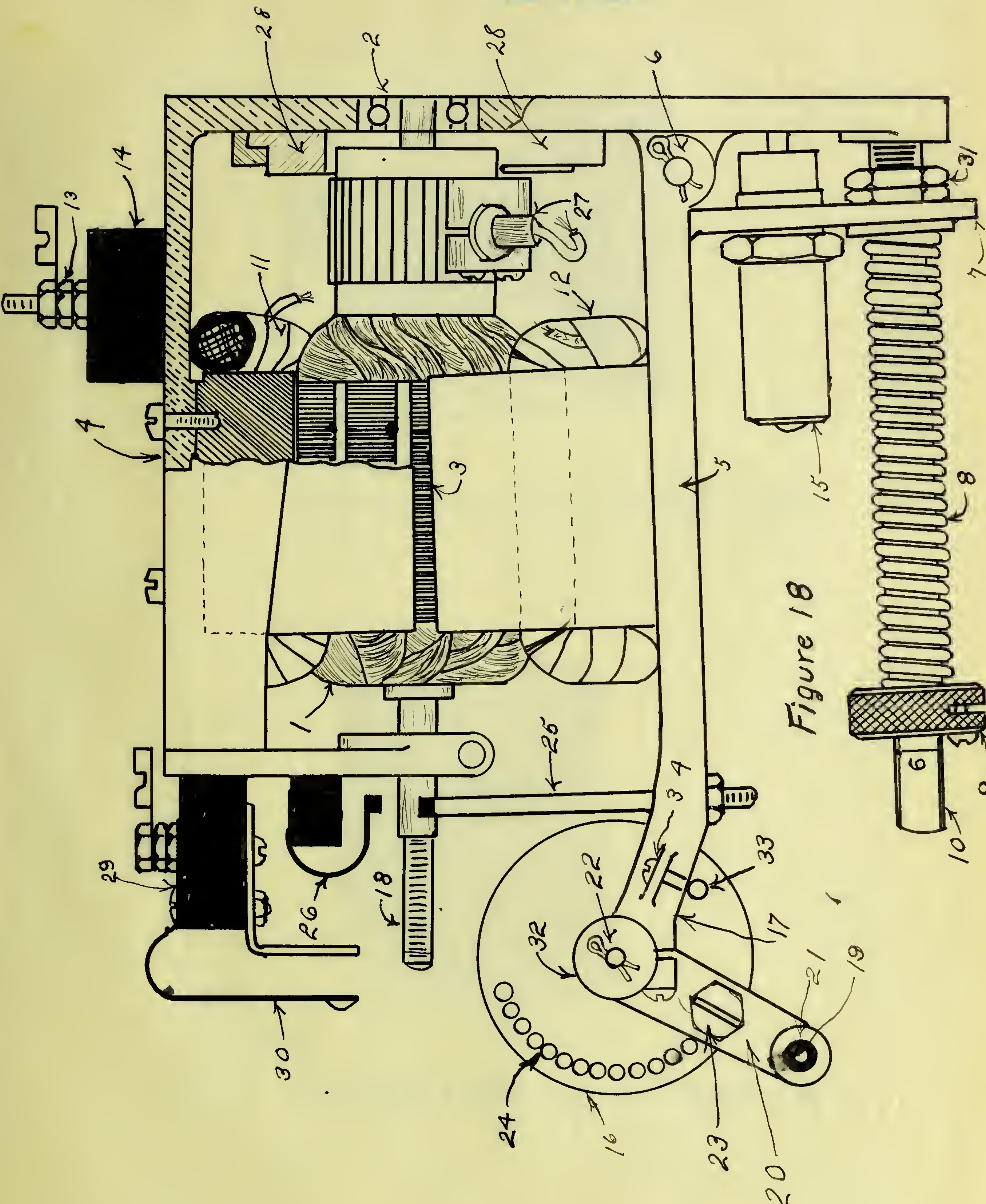
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Figure 18

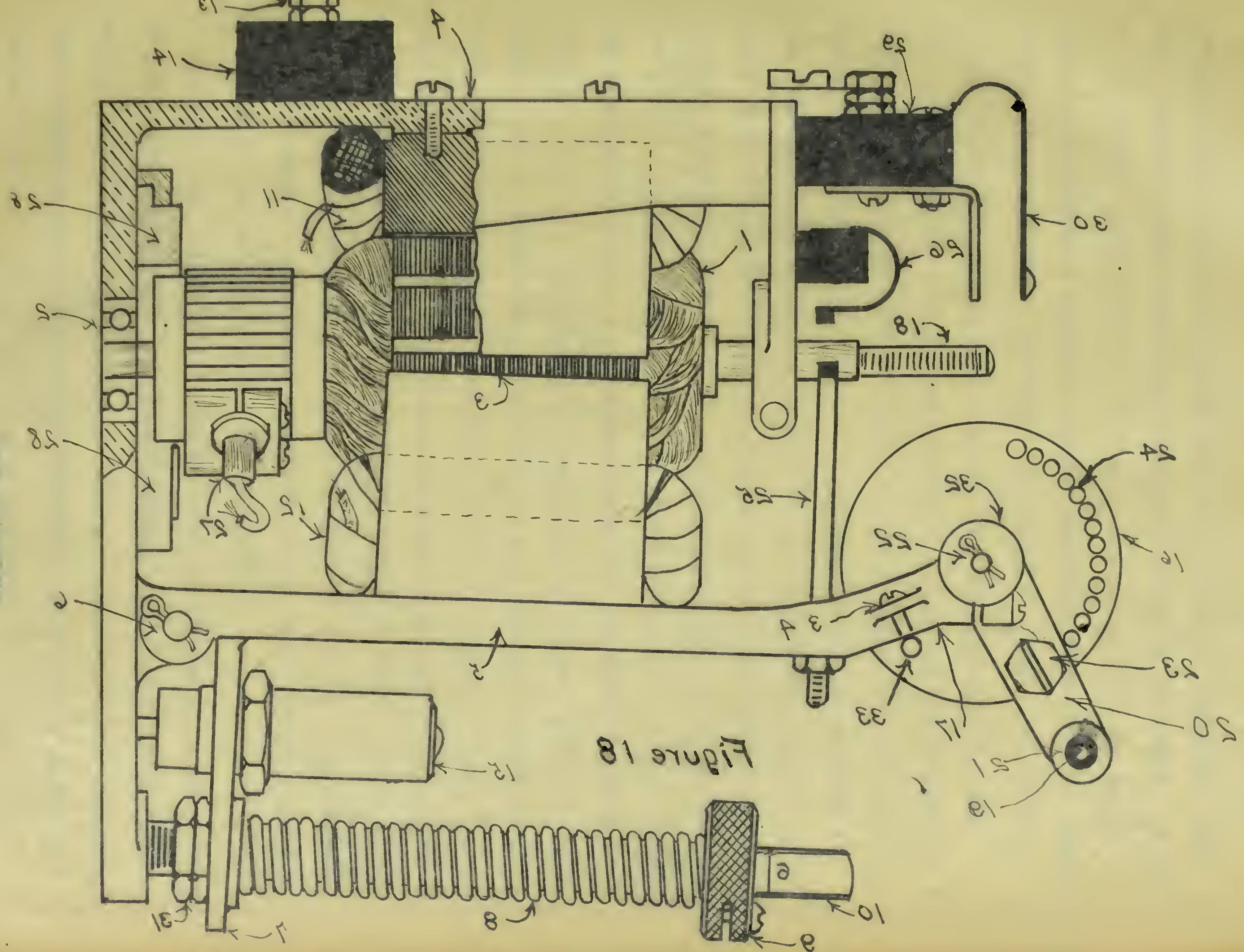
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Figure 18

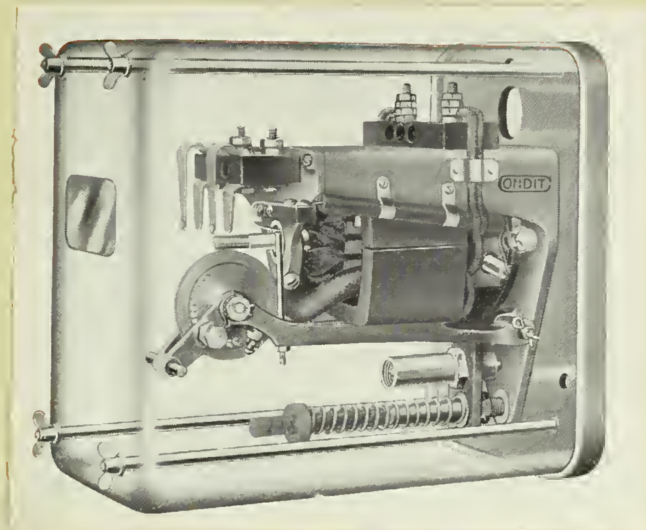

Fig. 19. Condit Relay with Glass Cover.

Fig. 20. Condit Relay with Metal Cover.

time of trip will be exactly proportional to the speed.

The relay gives curves similar to those of figure (3), the advantages of which are dicussed in detail in chapter II.

As for re-setting qualities, when the current goes below the set value before the trip circuit is closed, the lower half of the movable field drops and the motor circuit is opened. The movable arm re-sets at once.

Figures (19) and (20) show photo-graphs of the relay enclosed in two styles of covers.

V-COMPARISON OF THE DIFFERENT TYPES OF RELAYS.

The three types of relays which have been discussed are well known and in wide use. At the present time, the G.E. type is the most extensively used, but this is perhaps due to the fact that it is the older and better known of the three. In the authers mind, the bellows type is inferior to the other two types, at least as far as selective action is concerned.

There are several disadvantages to the bellows type which cause inaccuracies. Among these is the fact that the bellows is made of leather and may suffer from variations, due to weather, stiffening and so forth. However, the bellows are made from a very good grade of leather and the variations do to it might not be appreciable. Variations also occur on account of the dust and dirt collecting in the thimble valve,but with good attendance, this disadvantage becomes minute.

The greatest fault of the bellows relay is the fact that the time of trip approaches zero at very heavy overloads. This places it at a disadvantage for selective action, as is discussed in chapter II.

The Westinghouse induction type appears to have very good characteristics. It is claimed that it operates with the accuracy of a watt-hour meter, and this is no doubt true for moderate overloads. At severe overloads, the enormous leakage flux prevailing when electro-magnets are operated in proximity with permanent magnets, will cause errors. There is a magnetic shield to prevent this, but it is not very efficient at severe overload.

The greatest advantage of this relay is the fact that it has ver good characteristics for selective action. This means, of

course, when connected with the torque compensator, thus increasing the cost. The cost of this relay equipped with the torque compensator is about $48. This is rather expensive as compared with the bellows type, which can be purchased for about $25.

The Condit type relay appears to be a very good relay under all conditions. One of its chief advantages is the fact that the main circuit current does not flow in the armature and therefore protection of the relays under heavy overloads is assured. Owing to the few turns of wire which are in circuit when in normal position, this type of relay has a higher power factor and lower energy consumption than any other type of relay. This makes a decided advantage if the relay is to be used on current transformers that are used for instruments. The mechanism employed insures very good re-setting action.

This type of relay is perhaps the very best for selective action on account of the possibility of close time adjustment and because of its good characteristic time curves as shown in figure (3). However, its great cost is almost prohibitive, being in the neighborhood of $120.

VI-METHODS OF TESTING RELAYS.

The testing of relays is very important, both to the manafacturer and the central station man. The manafacturer must accurately test his product in order to keep up the standard and the central station man must run frequent tests on the relays used in order to see if they are in good order and able to give results if needed.

A good test is made by the Westinghouse Company. Four relays (figure 21) are connected as shown with circuit breakers in series. This test will show the selective action and also the time in seconds taken for trip. A cycle recorder, a device actuated by the alternations of the circuit, and having an arrangement to stop its motion as soon as the circuit is broken, is used for the time measurement. The four relays are set about .5 of a second apart. Application of overload current of any value should cause only No.1 to open; with No.1 blocked, only No. 2 should open, and so on. At the same time the cycle recorder registers the number of cycles passed over from the time the current is established until it is broken. Knowing the time taken by the circuit breaker to open the circuit, the time element of the relay can be easily determined.

Time curves for relays may also be taken by means of an electric chronometer, in which the establishment of the current in the main circuit causes a jog in a line on a rotating paper disc, and the establishment of current in the tripping circuit of the relay causes another jog. The distance between these jogs multiplied by the constant of the speed of the disc will give the time of the relay action. This data will give curves between

current and the time required to close the tripping circuit of the relay and does not take into account the time lag of the circuit breaker. Connections for a test of this sort are shown in figure (22). In order to get good average results, about ten trials should be made for each value of current. Figure (23) shows the data sheet for a test made on a Condit relay. This data shows the average time for each setting, the maximum variation for each setting, and the average variation for the entire test. In short, it shows just how much reliance can be placed upon the relay.

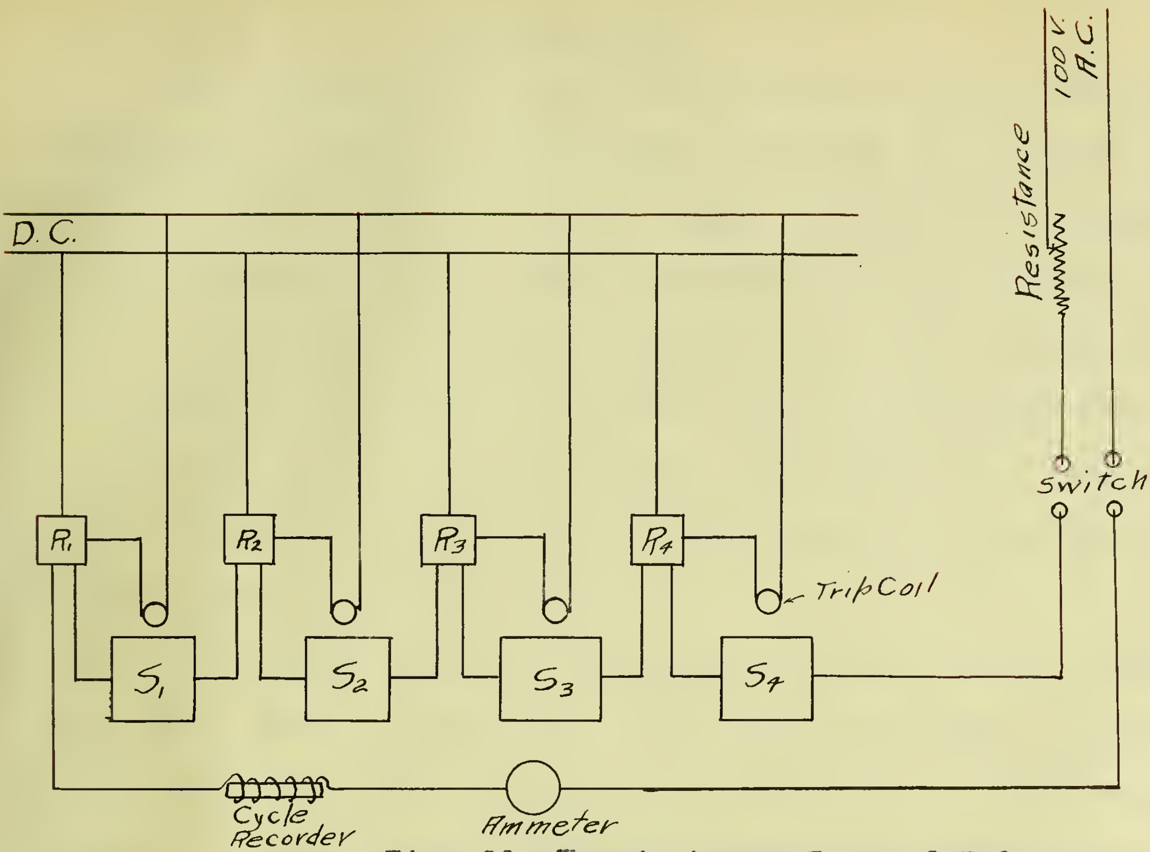

Fig. 21. Westinghouse Test of Relays.

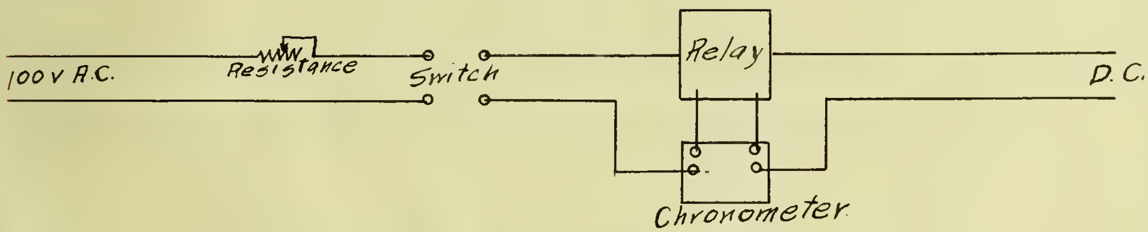

Fig. 22. Chronometer Test.

Amps	No. of Times Operated 1	2	3	4	5	6	7	8	9	10	Avg Time	Max Variation	
8	2375	2.558	2.508	2.433	2366	2.508					2.458	0.191	
11.2	1.917	1875	1900	1.850	1.900	1.842	1800	1800	1.775	1.892	1855	0.142	
15	1383	1400	1383	1.358	1375	1358	1383	1.366	1.383	1.366	1376	0.042	Inverse
20	1166	1133	1.158	1166	1200	1125	1.183	1.192	1192	1.217	1.173	0.092	
25	1.125	1117	1.125	1.100	1.125	1117	1100	1142	1117	1.117	1.118	0.042	
30	1.083	1083	1083	1.067	1.100	1.067	1067	1.092	1083	1100	1.082	0.033	
35	1.108	1042	1100	1083	1.075	1.067	1.075	1.083	1.067	1067	1.077	0.066	
40	1.050	1.092	1092	1.067	1.058	1.075	1.092	1.075	1.067	1.075	1.074	0.042	Definite
45	1.092	1.075	1.058	1.075	1.083	1.067	1.083	1.083	1.067	1.108	1.079	0.050	
50	1.075	1.092	1.050	1.092	1.067	1.067	1.067	1.050	1.067	1.092	1.072	0.042	
	Avg Variation of Total Curve → 0.074 sec												
	Avg Variation of Definite Part of Curve → 0.466 sec											CONDIT	

Fig. 23. Data Sheet for Condit Test.

VII-CONCLUSION.

This investigation has shown that the field of overload protection is still to be explored. Although the inverse time limit relay has reached a high degree of perfection compared to its prototype of ten years ago there are yet numerous improvements to be made. The relays which give the best results are too complicated and costly. The inventor and the designer have a problem before them in this regard. Undoubtedly the passing of the next decade will show a wonderful change in this particular branch of the electrical field.

It appears that no relay has as yet all of the features that go to make up the ideal type, namely; accuracy, high power factor and low energy consumption, reliability, permanency, simplicity of design, sensibility, mechanical strength, proper characteristics for selective action, and last but of great importance, low cost. Each of the relays mentioned in this article have some of these features, but none has all of them.

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